CAUSES AND IDENTIFICATION OF VIBRATIONS AT A ROLLING FRICTION BEARING, BALL BEARINGS

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Abstract: One of the most frequent sources of vibrations at machines with turning parts is the rolling bearing respectively the ball bearings, which according to deterioration of technical state, generate stronger and stronger vibrations. If a bearing is damaged early and the defect is on both rolling race and balls, the cause of damage is the same for all namely inadequate lubrication.

One of the most frequent sources of vibrations at machines with turning parts is the rolling bearing respectively the ball bearings, which according to deterioration of technical state, generate stronger and stronger vibrations.
In order to detect damaged ball bearings of working machines we use in practice different methods. As follows we describe the determination method of defect ball bearings by calculating the kinematic frequency of ball bearing components and identification of these in the frequency range of vibrations measured in the closest position of the respective ball bearing. From the mentioned identification results the respective diagnosis and based on personal experience I can say that it can be considered the most precise.
The kinematic and kinematic relations. Depending on excitation, periodical, pseudo periodical and random vibrations are produced in a frequency range of 0 Hz to 300 Hz, transmitted to the casing from the outer ring of the ball bearing.
The typical frequency of the rotation movement of the shaft is the rotation frequency:

$$f_{n_k} = k \cdot \frac{n}{60}\,[Hz]$$

$$(k = 1, 2, 3 \ldots) \qquad (1)$$

Where n, in min^{-1} is rotation of the shaft and k – the harmonic order.
The movement of balls in the ball race that characterizes the type and level of vibrations, the cycle and duration of stress, generates on the ball race periodical compression forces. These compression forces of the ball bearing are causing strains and the last ones are causing periodical vibrations.
Finding of peripheral speed and rolling speed of rolling balls on the ball race as well as the kinematic frequencies has a high importance for the diagnosis technique because these frequencies are components of the frequency range of vibrations of the ball bearing and motor shaft and can be recorded by measurement units.
Relation of movement will be treated as the general case of an angular – axial ball bearing where the outer ring is fixed and the inner ring is moving with speed n. In the diagram we present the geometry and the movement relation of an angular – axial ball bearing where 1 is the outer ring, 2 – ball, 3 – inner ring; D_E – diameter of outer ball race, d_m – average diameter of bearing, D_I – diameter of inner ball race, D_W – diameter of ball race W; V_E – peripheral speed of contact point E; V_W – center speed of ball; V_I – peripheral speed of contact point I; V_{II} – peripheral speed of ball race inner ring; ω_{II} - angular speed of inner ring; α – contact angle, n – rotating speed

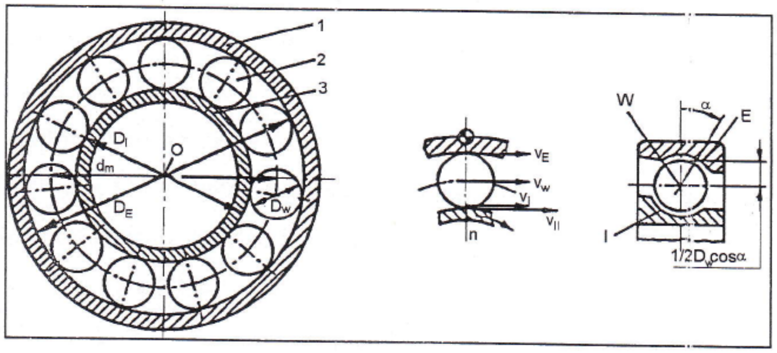

Fig. 1-The mechanical structure of the analised bearing.

The geometrical and kinematic relation of the ball baring depends essentially from load. This determines the phenomena that are produced at the surfaces in contact. In order to simplify the deduction for kinematic relations we take the following assumptions:
In the contact area there is a ideal rolling without sliding the influence of deceleration is negligible.
The contact angle α has the same value for the outer ring and inner ring
Based on geometrical and kinematic relations and simplifying assumptions, the following typical frequencies of the angular- axial ball bearing ([]) is resulting:
Rotation frequency of the ball race:

$$f_c = \frac{1}{2} f_n \cdot \left(1 - \frac{D_W}{d_m} \cdot \cos\alpha\right); \qquad (2)$$

Typical frequency (rolling frequency) of outer ring:

$$f_E = \frac{1}{2} f_n \cdot z \cdot \left(1 - \frac{D_W}{d_m} \cdot \cos\alpha\right); \qquad (3)$$

where z is the number of balls on one row.

Typical frequency (rolling frequency) of inner ring:

$$f_I = \frac{1}{2} f_n \cdot z \cdot \left(1 + \frac{D_W}{d_m} \cdot \cos\alpha\right); \qquad (4)$$

Rotation frequency of ball:

$$f_{WE} = \frac{1}{2} f_n \cdot \frac{d_m}{D_W}\left[1 - \left(\frac{D_W}{d_m} \cdot \cos\alpha\right)^2\right]; \qquad (5)$$

Rolling frequency of a irregularity of the ball on both rolling races:

$$f_W = 2f_{WE} = f_n \cdot \frac{d_m}{D_W}\left[1-\left(\frac{d_m}{D_W}\cdot\cos\alpha\right)^2\right]; \quad (6)$$

The equations are giving essential information for the diagnosis technique. These equations are generally valid for all types of angular-axial ball bearings (balls, rolls, tubes, quills).

In order to identify components from the range of the ball bearing's vibration that is giving information about the technical status of this it is necessary that the mentioned equations to be filled out in order to calculate the superior harmonic as well as the frequency of lateral range. In order to do this, the equations are filled out as follows:

Frequency of damaged outer ring:

$$f_{ED1_{l;m}} = l \cdot z \cdot f_c - mf_n$$
$$\Rightarrow (l = 0, 1, 2, 3, \ldots; m = 0, 1, 2 \ldots);$$
$$f_{ED2_{l;m}} = l \cdot z \cdot f_c + mf_n \quad (7)$$

Frequency of damaged inner ring:

$$f_{ID1_{l;m}} = l \cdot z \cdot (f_n - f_c) - mf_n$$
$$\Rightarrow (l = 0, 1, 2, 3, \ldots; m = 0, 1, 2 \ldots);$$
$$f_{ID2_{l;m}} = l \cdot z \cdot (f_n - f_c) + mf_n \quad (8)$$

Frequency of damaged ball race:

$$f_{BD1_{l;m}} = l \cdot f_w - mf_c$$
$$\Rightarrow (l = 0, 1, 2, 3, \ldots; m = 0, 1, 2 \ldots);$$
$$f_{BD2_{l;m}} = l \cdot f_w + mf_c \quad (9)$$

For the radial ball bearing, without angular axial load, the contact angle has the value α = 0°, value to calculate the characteristic frequencies, according to equations (4-11).

For the angular ball bearing, without angular load, the contact angle has the value α = 90°.

In this situation because the value D_W / d_m is small and can be neglected, the formula 11-12 are having the following form (13):

$$f_{CA} \cong \frac{1}{2} f_n,$$
$$f_{EA} = f_{IA} \cong z \cdot f_{CA}$$
$$f_{BA} \cong f_n \cdot \frac{d_m}{D_W}, \quad (10)$$

and the equations 11-13 are becoming:

$$f_{ED1A_m} = f_{ID1_m} \cong z \cdot f_{CA} - mf_n$$
$$\Rightarrow (m = 0, 1, 2 \ldots)$$
$$f_{ED2A_m} = f_{ID2_m} \cong z \cdot f_{CA} + mf_n \quad (11)$$

and

$$f_{BD1A_m} \cong f_n \frac{d_m}{D_W} - mf_{CA}$$

$$\Rightarrow \text{(m =0, 1, 2...)}$$

$$f_{BD2A_m} \cong f_n \frac{d_m}{D_W} + mf_{CA} \qquad (12)$$

With the help of the mentioned formula and diagnosis techniques we can determine the cause namely the defects of the ball bearing components.

The excessive increase of ball bearing's vibrations is due to the damage of these. Therefore defects of ball race, balls, cage can be produced or any combination of these. When identifying the causes of vibrations it is necessary to know the type of this because the ball bearings of different types are generating different signals according to load, clearance and construction.
If a bearing is damaged early and the defect is on the inner ring, the cause of damage is depending on the machine's speed and the damage is due to the camshaft, a misbalance or excessive angular load.
If a bearing is damaged early and the defect is on the outer ring, the cause of damage is not depending on the machine's speed and the damage is due to asperities of the cast or a split in the inner casing, a damaged surface between casing and outer ring or faulty assembly (inclined) of outer ring in the casing. If a bearing is damaged early and the defect is on both rolling race and balls, the cause of damage is the same for all namely inadequate lubrication.

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